new, as well as the contrivance of hanging it on pivots, in order to accommodate itself to the varying pressure of the hand.

No. VI.

ON WORKING IRON AND STEEL.

The Thanks of the Society were presented to C. VARLEY, Esq. of 1, Charles Street, Clarendon Square, for the following paper.

THE Society having favourably received the description of my late uncle's method of condensing brass, in which I endeavoured to shew the conditions which are requisite for the *extreme* and *uniform condensation* of metal previously sound; and knowing of how much consequence it would be to secure the sóundness of anchors, iron ties, girders, and other implements, to which the safety of human life and property are so often trusted, I am encouraged to pursue the subject, and endeavour to shew the means by which iron or steel may be rendered sound, and preserved so while working, and even during welding. But on a subject supposed to be so well known, and in which I must repeat much that is known, for the sake of connexion, it may be well to justify myself by shewing, in the first place, how inadequate the ordinary practice is to prevent unsoundness.

On Iron.

The welding of numerous layers of good iron together, so as to form one bar, is considered to render it much tougher and more trustworthy than if it had been wrought

out of one piece; for it breaks joint with, and equally mixes the strong and weak parts. But many stop here, believing they have done all they can; yet every welding may be discovered, which proves that a considerable degree of unsoundness accompanies this process.

If we notice the pump-handles about town which are constantly exposed to the weather, some are found where the continual wear from handling exceeds that of the weather: these acquire nearly the best polish that soft iron is capable of. But there are many in which the wear from handling barely keeps pace with the decomposition by weather; in these, the last weldings which united the different parts together to form the handle are most distinctly marked, and the various layers of which the mass has probably at different times been formed may be seen, very much resembling the longitudinal grain of wood. Here is sufficient proof of the want of homogeneity; and, seeing it is a constant attendant on welded iron, we are led to inquire what causes the necessity for welding. The answer is, first, the acknowledgment that iron is liable to invisible unsoundnesses, and that by welding they are likely to be distributed among sound parts and thereby equalise the strength of the mass; secondly, that there is a certain thickness beyond which the most governable hammers fail to produce the full effect of condensing the iron all through; and this thickness being far short of that required for anchors and other implements in which the utmost soundness and strength are wanted, such can only be made up by welding. Within that thickness there is no direct necessity for welding; but beyond it we have no means of rendering the whole mass sound. This necessity of sometimes having recourse to welding renders it of consequence to know what there

is in the process of welding that makes the laminæ visible.

When newly reduced iron is hammered till it becomes quite malleable and well closed or united, it may be considered homogeneal and sound, from its having no weldings and no carbon, this latter being carried off by the oxygen of the bar and beating. Whatever oxygen the surface imbibes in after-heatings is beaten off in scales while giving the required shape to the bar. It therefore remains as sound and free from oxygen as before; for oxide of iron is not only brittle, but incapable of uniting by welding with malleable iron.

But when two such masses or bars are heated for welding, they become again coated with oxide; and then, when laid one upon the other and submitted to the action of the hammer, the oxide is shut in, and union of the bars can only take place in proportion as the two plates of oxide are broken up and the subjacent malleable particles are brought into mutual contact.

From this intermixture of oxide and metal arises a spongy texture (more easily acted on by the air than the pure solid metal), which distinguishes the welding from the rest of the mass. If, therefore, several layers of good iron were welded together and beaten very much out without hammering the edges, on filing these square and cleaning the four sides, a little weak acid would soon distinguish the edges of the layers from their flat sides, and they might probably be counted.

But in ordinary practice iron is never left so: it is beaten in all directions, to give or keep the required shape, which so bends and distorts the layers that they are liable to be found in all directions; yet the lamellar structure remains, however much broken, and, when ob-

tained in a suitable degree, contributes to give that ornamental surface called *damask;* and as all much elongated iron, such as nails, wire, &c. shew a fibrous texture when acted on by weak acids, this intermixture of oxide may cause variation in that texture.

Now, the evils which arise from oxidizing the surface increase with the size of the weldings; for the great length of time the surfaces of large masses must be exposed to an urgent fire to obtain the welding heat, will cause so deep an oxidation that the union will be so much the more difficult to effect; for there needs a proportionate increase of hammering to break through a thicker coat of oxide, while the difficulty is increased of transmitting the force of the hammer through larger masses to the welding surfaces; so that the union is liable to be as much less perfect as the mass is greater.

Accordingly, it is very common to meet with anvils whose large beak, and sometimes other parts, are broken off at their weldings; shewing how very imperfect the union was, and that only at the edges, and seldom any at the centre.

And as an acknowledgment, by a workman, of the general deficiency of weldings, the Society, in 1820, rewarded Mr. R. King for his method of avoiding them, by forging the anvil-top, its beak, and opposite overhanging, in one piece, the base in another, and then welding the one on the other; so that in use this welding is the least exposed to strain.

Again: We frequently meet with iron-wire that will strip in two, like splitting a twig, and sheet iron that will split or peel up in parts: all shewing either the inability of producing complete union or of knowing when it is effected.

I have thus far traced the unsoundness which accompanies welding: next I shall shew what takes place when the weldings are quite sound; and shall pursue it, if possible, to the obliteration of every sign of previous welding.

If we recur to the melted carburet of iron, which is puddled or brought to a pasty state, and then hammered at a great heat till it has lost all its carbon, and till every part of the metal has united in one mass and become malleable, and observe what takes place during the process, we shall obtain a tolerably good hint for welding. The iron is still considerably divided by an excess of carbon, and probably by other impurities not easy to be defined. These are fast oozing out, and the carbon is burning at the surface, while the hammer is continually bringing portions of the iron into closer contact, so that they unite; and the pure metal being much stronger and tougher than the crude, it will keep together and combine with every particle of sound metal with which it comes in contact while the crudities are exuding; and this goes on, to the improvement of the quality, so long as any carbon remains; for, during that time, perfect welding must go on, because the carbon takes the oxygen and leaves the surfaces pure or clean for union. Thus the iron becomes one solid mass free from oxygen; for oxygen and carbon mutually take each other away in the form of gas, and leave the iron pure. Now, if ever so much hammered after this, the iron may proceed to perfect soundness and homogeneity; but it will be at the expense of the surface, which is detached in scales as it passes to the state of oxide, in which state, as I have before observed, it is incapable of uniting with metallic iron.

The conversion, however, of crude into malleable iron is never perfect till the mass is so reduced in thickness

that the welding force of the hammer is felt all through; and then if all the oxygen is removed from within, it may be obtained quite free from flaws (at least all but minute ones) and is fit for use.

Having thus established some thickness, up to which, with given tools, new iron may be obtained sound, we begin to increase that size by welding; and here begins a new and very different cause for unsoundness, which will require our farther notice.

Various means have been resorted to in order to protect the surfaces of iron from oxidation while in the fire, such as sand, glass, salt, or any thing that will bear the fire; but these require to be scraped off before the bars are put together for union. Now, any portion of such matter that is not removed is itself a cause of unsoundness, and when perfectly removed, a thin coat of oxide forms on the clean surfaces and is shut in.

In order to obviate this latter evil, the iron should be coated with carbon, as though it was to be case-hardened, by immersing or laying it on a bed of carbonaceous matter, kept very hot till it has imbibed enough to engage all the oxygen that would otherwise attack it during welding: moreover, this carbon blazing out at the surfaces, helps to keep up the heat till they completely meet together. The surfaces ought also to be slightly convex, that welding may begin at the middle (that part being liable to receive less impression from the hammer), and proceed gradually to the edges: thus the blisters that are liable to be produced from the union of oxygen and carbon are more likely to be beaten out. And more particularly as the masses singly were as thick as the hammer can govern, and now being doubled, its effect is lessened at the welding surfaces, therefore more care is required in

the mode of bringing them together; for unless each part is kneaded together enough to adhere before the heat lowers, some parts will only be beaten close without union; and all after-heatings affect the outside more than the joint. Also, if any air is shut in, this likewise retards the union; but a convex surface gives the best opportunity for it to escape.

Next, supposing the iron protected as usual, if, at the moment the substance used for this purpose is well scraped off, the surface is sprinkled with good cast-iron or, still better, with cast-steel filings, this addition will introduce carbon enough to engage the oxygen, and a sound welding may be expected. Here the operation is similar to the original reduction of the iron to the malleable state; for perfectly clean iron unites very readily if brought into close contact at a suitable heat.

This process for uniting iron which otherwise was too thin for welding has lately become public, and by some has been called soldering, under the notion that the cast iron melted between the surfaces.

Iron is too thin for welding if it cannot retain the heat long enough under the hammer (or when the remaining good metal is not enough to squeeze through, or mix up with the oxide) to unite, without being smashed to pieces by the hammer; or if so much flies off in scales that the remainder becomes useless. But by the introduction of highly carburetted iron, the oxygen is consumed and the heat thereby retained a little longer; and the metal becoming all good, or restored, there is rather an addition than a diminution of weldable substance; and a much less use of the hammer will bring the whole into union.

Now, seeing by this means much thinner iron is united

than formerly, it is desirable to apply the same process as completely to large work. For, though the mechanical obstacles appear so opposite, the opposing agent (oxygen) is the same, and is nearly in proportion to the masses.

Small work, being quickly brought to the heat, is less burnt than large masses; for these, requiring much time to arrive at the necessary heat, receive a deeper coat of oxide. Small work, however, is more disfigured in proportion, by the beating requisite to cause union; whilst in large work the quantity of metal between the hammer and joint resists the operation.

In one case the work is worth nothing unless the iron is preserved; in the other the joint is not sound unless oxygen is excluded, because it can never get so much brisk kneading together as to overrule the enclosed layer of oxide, and force union.

A third method I would propose for very large work, is to protect the surfaces in the most convenient manner while coming to the heat; then carefully cleaning them and laying a thin sheet of clean hot steel, that has been highly carbonized, between them: this would secure a very sound and equable layer of metal all through the joint, the carbon of which, if more than enough to reduce the oxide, would still not impair the soundness of the metal, and consequently do no harm to the joint.

If by some of these means, either of excluding oxygen or removing it in the process, we are enabled to effect a sound union, we may add layer upon layer of sound metal, till we have obtained the largest required mass. Yet this may, perhaps, be only apparently sound; for here another evil is liable to be introduced, which before was stated to need our attention; and if this is allowed to enter, it will increase with every additional layer.

In order to explain this, let the layers be supposed to be added in succession, all on one side of the first, bearing in mind that we are using the thickest layers which our hammer can govern.

When two are welded together, the upper one is stretched most by the hammer; it is therefore pulling the under one with it, which, if it cannot do, it will divide the exertion by curving a little to it. Now here at once the mass is in an unnatural state of tension, the under piece being stretched like a cord, while by its force it is striving to bend the upper one like a bow. Now, a third layer added on this, will, in like manner, be stretched more than the under ones; and while endeavouring to stretch the second one like a cord, it becomes the antagonist of the first, and would overcome its power to bend the second; but as its relation to the second is precisely what the second is to the first, a strong tendency to a curve is still the result. Now, on proceeding to add the fourth, fifth, sixth, &c. layers, we are continually increasing the stretching force on one side. Therefore, these additional layers must either all bend, or the under one be so stretched as to break or become unsound; for the farther the bottom layers are removed from the hammer, the more do they act merely like an anvil, suffering less and less alteration from the hammer.

Now, if instead of adding only on one side, we added as many layers on the three other sides (leaving the first as a central nucleus) while hammering the outside layers, they would all be enlarged; the inner ones serving little more than the office of an anvil, are, therefore, stretched till they break.

This kind of mischief begins with the first welding, and increases with every layer, and is greatly increased

by the quantity of hammering required completely to form and finish the work. For the more the outside is extended by the hammer, the more the inner part is stretched; and as this will bear but little of extension without parting, the mass must become unsound. Agreeably with this, it has long ago been observed, that large masses hammered beyond a certain degree lessen in specific gravity instead of increasing, and therefore it was supposed that a large ball might be hammered till it became hollow. Now, whether the layers be added in succession, or are all heated for welding together at once, the effect will scarcely be altered, for it will require as much hammering fully to effect all their unions, and there will be the same gradation of the hammer's effect; for the outside will be drawn out in length more than the inner. This is shewn by trying to lengthen a cylinder by a hammer rather too small; for then the centre not lengthening equally with the part directly acted on by the hammer, the ends will become hollow, and the force of the extended outside will stretch the middle parts to unsoundness. The use of enormously large hammers will carry us farther in size before central unsoundness takes place, but then the surface is the more furiously smashed about.

It remains to offer means of preventing or diminishing this central unsoundness; for though in large work the tools would be expensive, yet where the repetitions are frequent, that is of less consequence; and if one ship was saved by the greater strength of its anchor, it would surely be an outset against the most expensive tools.

The bars, which are to be united into one great shaft or stem, should be all of one length and of the full width; then an anvil or bed of iron should be provided, so large

as to contain a recess of the same dimensions as the intended shaft. Through the bottom at each end, and flush with it, iron posts might stand so that they could be raised by levers at their bottom when the work required to be lifted out. Now, prepare two of the layers for welding, and put them into the recess, and have a stamper or welding hammer square-ended, as wide as the recess, and let it drop from a carriage travelling parallel with the recess; in this case there is no room for extension either in length or width, the metal can only close, and as there is no lateral spreading to make way for the hammer, its force will be directed more effectually downwards; but as its face would be too broad for its best effect, two men, with a frame like a hand-barrow, might carry a short cylindrical hammer-like punch under the stamper, and distribute the blows equally all over. Where this cannot be done, placing the hammer over an anvil, with two heavy cheeks adjustable to the required width, would prevent lateral spreading and lessen the evil, though it could not prevent the longitudinal stretching. But by whatever means the workmen can prevent all extension under the hammer, soundness will be preserved. The above process being performed on two layers, then bring the mass thus produced to a welding heat, and add a third layer, and so on in succession.

If a ball of clay or putty is rolled into a cylinder, it will shew hollow ends, proving the outside to have extended most; and the centre, being cracked by the stretching, at last breaks the cylinder all through, and it falls to pieces with cracks sharper than the softness would lead us to expect. I have seen brass wire full of cracks at which it would break, occasioned either by very hard drawing or brittleness of the metal, and these breaks were

convex, fitting into concaves, shewing that the centre had travelled faster through the hole than the outside; for the convex was towards the hole before it had passed, and from it when passed, and the last end of wire is frequently hollow.

Now, seeing large masses are so liable to acquire internal unsoundness, and the weldings also difficult to obtain sound, I would, in constructing anchors, totally avoid all weldings across the pull to which they are subjected when in use.

I would therefore take new iron that has only been reduced to the malleable state, in pieces long enough to forge into the complete form of the intended anchor, without flukes, and thin enough to be quite manageable under the hammer. Having provided a quantity of these, I would weld together (as previously mentioned) by carburet of iron sprinkled between them, a sufficient number to give the required thickness, with some contrivance to prevent all extension, but should prefer a recess capable of receiving the whole anchor. This would produce square limbs; and I should prefer chiselling off the corners to hammering them in; for if they were hammered in, it would put some parts in a state of greater tension than others, and destroy that equal ease throughout, which is so very essential in an anchor, where every part should contribute equally to bear the strain; for those parts that are left in a state of tension chiefly bear the pull, and must give way before the others can come to their full tension; therefore the anchor breaks. Perfect soundness of the iron, an arrangement of the weldings so as to be in a line with the pull and ease of all the parts, or an equality of their state and freedom from tension, are the three most

essential requisites in an anchor, after its form has been determined.

From these considerations, I think it will appear, that many anchors are rendered unsound by the hammering, and that the metal is liable to be put into such an unequal state of tension, that one part at a time only bears the strain; so that with the weight of a large anchor we have only the strength of a small one; and when this is the case, can we wonder at their breaking?

There remains yet another view in which the use of large implements should be considered; namely, at what thickness can any given material be used with the best advantage. This leads to the inquiry, whether there are any limits in this respect as to thickness and length; and if so, what is their nature, and do any implements exceed those limits.

Now, an anchor is the largest hook in use, and is exposed to rougher or more violent usage than any other, and that even in proportion to its greater size, on which account it ought to possess every good quality of metal. But I fear this inquiry will shew that the largest anchors do exceed the limits of some of the most important qualities.

To seek for these limits, we must look at matter much reduced in size, and compare it with the largest masses, and we shall find a greater contrast than in size.

Small pieces fall from any height without breaking, the blow they give or receive not being equal to the force of cohesion between their particles. Now, on increasing their size, the sectional surface to be broken increases as the square, while the weight increases as the cube, therefore large bodies break from falling.

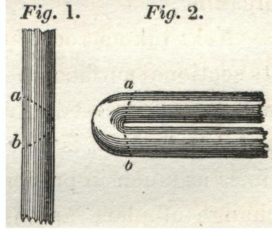
If we sufficiently reduce the thickness of very brittle

materials, such as glass, they are found to be flexible: glass may be drawn out so thin or fine as to bear twisting together and forming thread, and it bears throwing about; while the same substance in rods two or three inches thick, will break rather than bear bending enough to be discovered by the nicest measurement.

If we could have wire so small as to consist of one line of particles, it would lose all character of stiffness, and bear unlimited bending (such an imaginary wire may be imitated by a line of small magnets between two large ones); and if it consisted of three or four lines of particles, no bending could remove them out of the sphere of their mutual attraction; such a wire, therefore, would never break. Now, the smallest soft iron wire bears so much bending about, that it appears, in this respect, more like lead than iron of large dimensions.

This flexibility continues so far, that soft iron wire, about one eighth of an inch thick, may be bent double, while cold, without fracture. Here the outer portion *a b*, fig. 1, about two thicknesses long, is bent and stretched into the curve *a b*, fig. 2, about double the former length; the fulcrum round which it begins to bend is probably one-third within, but it must ultimately remove to the outside, as will be seen by the figure.

Fig. 1. *Fig.* 2.



We may observe that a considerable angle is made before there is much stretching: this is of the greatest consequence, as it immediately engages a longer portion of the metal to stretch and contribute to the bending; for where there is any curvature the metal is stretched: this will be understood by bending wire into a spiral

round a very small axis, when it will have a constant succession of bending parts, and the whole outside will be stretched. Now, after the angle is made, the outer side, while bending and stretching, is forcibly pulled closer towards the fulcrum, therefore the change of place of the particles is not so great as it appears; and the reason the wire seems not to have lost any thickness at the bend, is owing to the bulging out of the inner side, nearly making up for what is lost on the other: the inner portion is so hardened by the pinch, that there is a little lateral sliding round it while making the bend.

Now, supposing we have begun with the thickest wire that will bend double, let us take some of twice that thickness, the sections of the bending portion will contain four times the surface, but the quantity of metal engaged in bending is eight times as much; therefore the amount of its cohesion is now doubled; and in consequence this wire cannot be bent so much as the other without breaking.

Next take a rod of ten times the diameter of the wire; its sectional surface, the cohesion of which resists breaking, will have increased a hundred times, while the quantity of metal to be bent is increased a thousand times; this is ten times as much in proportion to the cohesion, and the lateral change of place among the particles requires also to be ten times as much: but we supposed the first wire to be the thickest that would bend double, consequently there was all the change of place among the particles that the metal could bear; but in this latter case, ten times the former amount of change of place being required, with ten times the proportional quantity of metal to the cohesion, the rod must rather break than bend.

Steel or iron wire, 1-twentieth of an inch thick and a

foot long, will bear throwing about any how, and suffer little from bending; but if, with the same proportions, the thickness be one foot, the length will be 240 feet, and its weight somewhere about 80,000 lbs.: this, it is evident, could not bear falling from a height proportionally great, or even being lifted from one end, like the smaller.

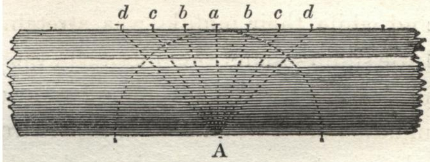
Thus the power of bending decreases as the thickness increases; therefore, in very large masses it is almost nothing; and this same reasoning applies equally to the springing power of large masses.

Now, seeing that brittle bodies become flexible by reducing their thickness extremely, so the most flexible bodies become, as it were, brittle by greatly increasing their thickness: therefore, I think we may come to this conclusion, that there is a given thickness at which metal loses all power of springing or bending, and therefore a blow powerful enough to require its yielding will be sure to break it, because it cannot yield in any other way.

We may notice that, after a certain quantity of bending, the iron becomes so unequally stretched, that some parts are rendered weaker than the rest; these cannot bear the same exertion, and so must give way.

When a bar receives a blow, or takes one by falling from a great height, it must either spring, bend, or break, at the part struck, because the section there is the shortest, as at *a*, fig. 3. Supposing A the fulcrum or blow, the sections *b c* and *d* rapidly increase in length, and therefore soon limit the portion whose strength has to resist or oppose the momentum or weight of the two ends, and when it bends,

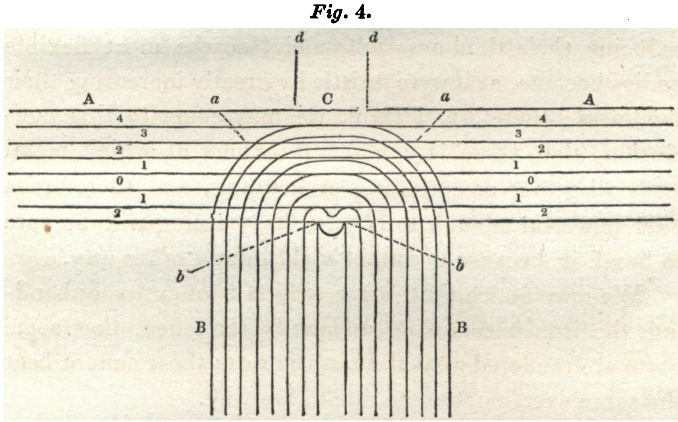
Fig. 3.



the section *a* is most stretched, *b c* and *d* succcessively less as they are longer; therefore *a* is the only part stretched to the utmost; but when a curve is made by a little bending, then there is just so much added that can stretch like *a*, or at least like *b*.

It may, perhaps, be allowed here to give another view of what takes place while bending. We will suppose a bundle of square rods A A fig. 4 perfectly fixed together at their ends, so that they cannot slide, to be forcibly bent as to B B. In this case the rod marked *o*, or one near that

Fig. 4.



place, would simply bend; No. 1 below it, would thicken and shorten; while the bottom one 2 would bulge out making three bends like the letter M; then Nos. 1, 2, 3, and 4, above, would all have to stretch as well as bend, and while their middle was stretching there would be a little sliding round the fulcrum or the two shoulders formed in the lower bars, the upper bar stretching most, and the middle part C in all four of them stretching more than the adjoining parts, as is shewn by the sections in fig. 3. Now, if instead of the rods being so small as to bear bending, we suppose each rod to be the thickest that will

bear to be bent so much, it is evident they will not bear the additional quantity of stretching and sliding requisite to allow of their taking the form B B, for the parts *a a* would have to descend to *b b*; a portion *d d*, as wide as the fulcrum is thick, is pulled straight just before rending, and in all cases of bending that straightness is a signal to go no further, for the bar will break.

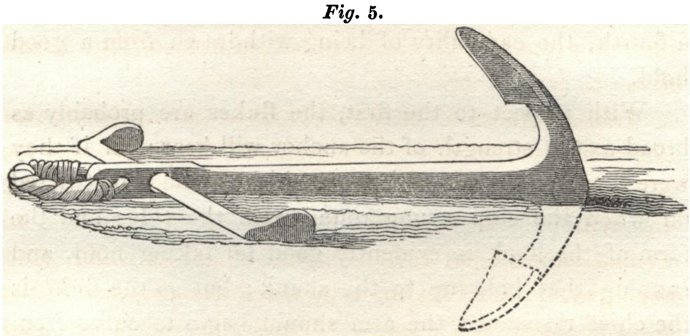
Now, seeing the power of bending or springing decreases as the thickness increases, and that the weight (the momentum of which endeavours to break any body which falls suddenly on a hard resistance) increases as the cube while the strength increases only as the square, I think it will follow that anchors ought to increase more in thickness than in size, in order to make up for their loss of flexibility, and enable them to fall without breaking.

This leads us to inquire whether anchors are formed so as to answer equally well their three principal services: the first, to be sure of taking hold; the second, to bear the great strain and jerking to which they are subjected while in use; and the third, to bear falling; and sometimes a fourth, the capability of being withdrawn from a good hold.

With respect to the first, the flukes are probably as broad as the strength of the anchor will bear; for if they were broader, they sometimes would be liable to be twisted off when the ship swung round with the tide; and the form of the hook is evidently good for taking hold, and running that hold up to the shank; but as the fluke is the chief resistance, the arm should begin to curve from the fluke gradually into the shank: but the wooden stock which obliges the anchor to take hold, offers as much surface to the ground as the fluke does; this added to the rising angle of the pull, prevents the whole anchor from

diving through soft ground to a harder bottom in which it can hold. The power of diving might be given by using iron stocks, made to turn in the anchor, with the arms fig. 5 flattened, and round disks at their ends turned inwards enough to make the flattened arms present their edge to the sand or mud in such an angle as to be able to dive. Again, it is not well to drop an anchor with any additional weight, as that would tend greatly to break it; but if a stop were put on all cables three or four fathoms from the anchor, and a weight like a collar allowed to run down the cable to this stop whenever the anchor was found to drag, it would cause such an angle in the cable as to make the portion between it and the anchor lie on the ground and pull horizontally: this weight would also act like a spring, for when the ship tugged at the cable, endeavouring to straighten it, it would have to raise the weight before the anchor could feel the tug, and then it would never be so sudden or so much upwards as without a weight.

Fig. 5.



With respect to the second condition, the action of a hook is the severest strain that metal can be put to; therefore, nothing but the most careful gradation of form, regularly increasing the strength from the stock to the

bow and from the fluke to the shank, and curving the shank better into the bow or arms with really sound metal, can distribute the strain equally.

Thirdly, the bearing a fall: an anchor is so formed that it cannot drop on a hard bottom without strain somewhere; and as we can only meet this by increasing the thickness more than the size, and as with this thickening it will be gradually losing the form of an anchor and approaching that of a block, it becomes a query whether, for the largest anchors, Parks's mooring block (which was rewarded by the Society in 1818, Vol. 36) is not the best, weight for weight, because it will dive till it finds hold, and a stopper may be put on the cable to prevent it from diving too deep to be easily withdrawn.

There are two somewhat similar operations by which metal is fitted for our use that deserve our consideration, because in one it evidently loses strength laterally, although it gains it longitudinally. These are wire-drawing and rolling out into plates: in one case it is drawn through holes successively reduced in size; in the other it is drawn between hard rollers successively placed nearer to each other.

This produces a character rather extraordinary for metal, for it becomes fibrous; and this texture may be satisfactorily shewn, by submitting a piece of it to the slow action of weak acid. Some have attributed it to crystals which kept their separate character while being elongated. But if we carefully trace the progress of the metal through the holes or between the rollers, we may probably find sufficient cause for an elongated or fibrous texture.

The metal is caused to pass through the holes by

pulling and not pushing; therefore the quantity reduced each time must be small compared with the thickness of the wire, because it is the mere tension of the reduced part which causes a complete change of place among the particles, or the squeezing of larger rings or short cylindrical portions successively into a smaller size, and elongating them in proportion. This elongation takes place in the hole where the metal is stretched nearly to the utmost, and it may be considered as analogous to drawing a cylinder or core out of a tube; and this core is so much stretched as to receive into itself the whole of the outer coat, which thus sinking in becomes part of it and follows by its cohesion. Now, as these successive rings are too large to go through the hole, they cannot contract and dive into that below but by a longitudinal sliding of the particles, some sliding aft to let the others close and proceed through the hole. Now, as the elongation is unlimited while there is room to reduce, the centre would be torn asunder, did not the outer metal dive and fill it up; then, as cohesion, or the power which resists parting, is the cause of this, the whole portion at the hole may be considered almost as in a liquid state while passing through it. During this motion and change of place among the particles, if there is any sort of polarity in them, this is the time they are called into action, and can arrange themselves, and that arrangement must be longitudinal; but the longitudinal sliding of the particles to allow some to proceed first through the hole, and the continual wedging of portions of the outside into the central parts to supply the current of particles through the hole, (for it is like a current) the particles re-arranging themselves and following by mere cohesion,

appears sufficient to produce a tendency to longitudinal fissures, by which the coherence is somewhat weakened, although no real division takes place.*

In the flatting-mills the revolution of the cylinders helps to carry the metal through; in that it differs from wire-drawing; but though there are no side stops, the metal scarcely spreads any thing in width, proving that there is no pressure of the particles together laterally, but that the mass is elongated just as the thickness reduces; here the rollers pinch tight the reduced part and forcibly carry it through; while the thicker part, like a wedge, refuses to follow, so it is stretched somewhat like wire-drawing and the surface is driven back in waves. Here the whole action is lengthwise, and each line extends without regard to its neighbouring lines, so that its lateral adhesion is weakened; and, as a thin plank will bend lengthwise, but will split rather than bend crosswise, so will hard rolled plate metal. Annealing and hammering once or twice till hard again, by distributing the extension in all directions, removes this parallel fibrous character. This change of character, according as the metal is worked, shews that none is so strong as that which is beat in a recess; and I think no fibres could

* When reducing some thick wire in the lathe, to make a small screw with a large head, it proved so unsound at the centre as not to bear reducing to the required size; it did not break off, but tore aside; and on twisting it about with the pliers, the whole of the reduced portion appeared fibrous, so that the wire seemed to have a pith within it. In this instance the centre must have stretched more than the outside could supply while drawing. It would be desirable to try which would give the soundest centre,—the reducing wire through the fewest possible number of holes, or greatly increasing their number and bringing the wire down very gradually; then drawing some very slowly, and some as quick as possible.

be discovered in such metal; for, if I may use the expression, it would be one fibre spreading every way; in fact, it becomes quite dense and homogeneal.

I have now endeavoured to shew that oxygen entering with each welded surface deteriorates the iron; and have proposed some and pointed to other means which have been found capable of avoiding it.

Also, that the difficulty of transmitting the force of the blows to the inner surfaces increases with the thickness, and therefore limits the thickness at which sound welding can be obtained.

And, when the hammer is used for lengthening a mass, the outside is chiefly elongated, from the effect of the hammer regularly decreasing as the centre is farther from the surface; so that, at last, it receives no impression, but, with the mass below it, serves only the office of an anvil merely helping the hammer to extend the outside, in which case the centre always becomes stretched, and thereby weakened, and sometimes torn asunder; and as each side while lengthening under the hammer endeavours to bend the mass, it causes an alternation of the stretching or springing, so as to facilitate the cracking of the centre.

Thus, while small masses are rendered dense and stronger by the hammer, large ones suffer loss of strength if very much hammered.

On Steel.

Steel is made by combining carbon with iron: it is done by immersing the iron in carbonaceous matter at a white heat and excluded from air, till it has imbibed enough all through. It is made to receive more or less,

according to its intended use. Pure iron is not altered nor increased in hardness by sudden cooling from a red heat; but the small quantity of carbon which is combined with it to form steel, greatly increases its strength and toughness, leaving it both malleable and ductile, and gives it that peculiarly valuable property of becoming extremely hard, if suddenly cooled from a red heat by immersion in water or by any other means. With this first dose of carbon it is called *mild steel,* because it possesses all the valuable properties of iron, with increased strength.

A larger quantity of carbon increases the hardness of the metal, and makes it more brittle when hardened by sudden cooling, and also renders it fusible; therefore it is called *cast steel,* and being less malleable, it is more difficult to work.

When steel is made without fusion, by immersing it in carbon, the process is called *cementation;* and it is called *blistered steel,* because, while the carbon is entering, it meets with oxygen, or hydrogen, or other impurities, which it causes to become gas or vapour, and this blisters the steel. There is a considerable quantity of steel brought to market with defects which appear to be the remains either of these blisters or of the weldings that follow.

Cast steel, being made by fusion, admits of an equal distribution of carbon, and of the escape of every particle of gas, vapour, or any other substance not compatible with it at so great a heat, leaving only such as can combine with it; therefore it is the only steel we can be sure of obtaining quite sound.

The question whether steel contains any thing besides carbon and iron, is chemical. A good workman only requires metal perfectly free from flaws, and quite homo-

geneous, and that will harden at the lowest heat; for this last test supersedes all others in proving the goodness of steel and its fitness for the best purposes.

The soundness of cast steel renders it most desirable to use; but the excess of carbon makes it too harsh, and therefore more difficult to work; but by frequent heatings and hammerings it may be reduced to the state of mild steel, the excess of carbon burning out while forging, and then it must be the best steel for general use. Yet shear steel predominates in the market, and more particularly in the various manufactured tools, probably from being cheaper. Therefore it is desirable to discover its faults, the better to cure them.

Perfectly pure iron cemented in pure carbon would probably make steel without blisters; but as in practice blisters are produced, there must still be oxygen in the iron, or some other substance that is turned into gas or vapour by the addition of carbon. Now, the blisters are most on the outside, but why not equally throughout? The answer is, the strength of the metal resists the assumption of the gaseous or vaporous state. Is not, then, the blistered outside purer or better steel than the centre? for though the carbon penetrates to the very centre, is it not obliged to combine with the oxide of iron and other impurities in the solid state, and remain so, the strength of the metal forbidding the change by which it would have a chance of escape? Again, if permanent gas is formed in any of the small blisters within, how is it to escape? the hammer may greatly reduce the size of such blisters; but will there not be small flaws or cavities remaining? If, in addition to this, the iron contains the bases of the earths or alkalies, or the earths themselves, these latter may be reduced by the joint action of the

carbon and iron, and then being vaporised by the heat, the metal may be blown into blisters. In this case the cavities would probably be coated and thus rendered unweldable; these flaws would then spread with the metal while working into plates or rods, and the mass, though close, would not be united.

The blistered steel must be unequally carbonised, the outside containing most; it is fitted for the market by drawing out to greater lengths by the hammer, then folding double, and welding together again; then drawing out, and again welding several times. This mixes the various parts together, and thereby distributes the carbon more equally, and condenses the metal; it is then called *shear steel,* and considered fit for use. Now, these weldings are liable to introduce flaws,—first, by imperfect union; secondly, by the carbon burning out of the surfaces that meet together, giving a stratum either of iron or of steel with less carbon; and these being softest, would give way during the extension of the steel.

Now, whether from original blisters, or similar cavities from imperfect welding, such defects do very largely accompany this steel; and it is a question, whether any process short of fusion can totally remove them. Yet long-continued forging greatly improves the soundness and homogeneity.

Besides flaws, there is another defect often met with in steel, it is said to have pins; for, when filing or turning, it appears to have knots or pins in it harder than the rest of the metal. A similar defect occurs in brass, when, through the negligence of the founder, it contains iron or steel filings; also in wood, with hard knots: but this evil is worst of all when it occurs in steel, which naturally is hard to work. I have met with it in all degrees, from

mere harshness up to real hardness; so that while turning in the lathe, these parts would remain projecting out, and damage the tool rather than be cut away. I have filed some off, and then found their hardness nearly approach that of the file. This inequality of hardness causes the work and tool, though held by the rest, to spring away from each other, rendering it difficult to turn true. I think it is often caused by portions of the metal being over-steeled, *i. e.* so completely charged with carbon as not to soften by slow cooling. Another cause is stated by Mr. Clement, who broke the steel across these pins, having filed away the back to render it weak enough to part at the right place, when he found a cut or division, on which account he attributes the flaw and its hardness to oxide of iron, which prevented the parts from welding together; and as oxide of iron is known to be harder than steel, by its being used for polishing that substance, it most likely will cause hardness where it occurs. It would be desirable to ascertain the state of the surface of the deepest blisters, to know whether they are alloyed or oxidised, or in any way differing in their state of carbonization from the most solid parts. When such spots occur from oxygen, the adjoining parts must be iron; for there will be a gradation from oxide through iron to the steel, therefore the circumference of such a spot would be softest.

An excess of carbon renders steel harder and more brittle, therefore inequality is liable to occur. This is illustrated by iron hardened while casting; and of that which is intended to be soft, portions are frequently found hardened by the wet sand: these parts near the outside break with a more glassy fracture than hard steel. Good steel, hardened by plunging from a red heat in cold water,

will always become soft by slow cooling from such a heat; but this hard cast iron does not: it requires burning several hours at a red heat, and must not be smothered by fuel to prevent decarbonizing, but, on the contrary, should be exposed to the current of air, that some portion of the carbon may burn out while the remainder has a tendency to equalize itself; then, if slowly cooled, it is found soft. Now, the knots or pins in steel are not softened by slow cooling, and to burn them out would spoil the steel, it having no carbon to spare but in the pins (supposing this to be the cause of their hardness); and keeping it hot in close vessels will not produce equality sufficient for any good purpose. Even cast steel is liable to long veins of harder portions than the rest. All these defects shew the need of farther attention to the improvement of steel, and for this purpose two sorts of hammering are requisite.

The first should be at a forging heat, to knead the parts, and keep them moving among themselves almost like a paste; and should be continued till the different qualities are not only intimately mixed, but, if I may use the expression, really dissolved in each other, producing perfect homogeneity; for the carbon being thus spread, will discover every particle of oxygen, and (it is supposed) will expel it, and the metal will be rendered as sound as we can expect from cemented steel; for if free from oxygen and all alloys, except the carbon, there is nothing to prevent a perfect union of all the parts while under the hammer. Good steel consists of that proportion of carbon and iron which forms the strongest and toughest compound; each best portion, therefore, when brought into contact by the hammer, remains so, and resists its force the more from the greater cohesion of its particles;

hence the redundant or deficient portions suffer most kneading, till they are all equalized, and the cruder impurities are either beaten out, or formed also into a homogeneal compound with the whole mass.

Having thus far obtained sound steel, it is yet by no means in a good state, being very unequal in density, and in a state of distraction—some parts close and dense, others squeezed out, and some nearly rent asunder; therefore a second hammering is necessary at a particular heat, and under circumstances as similar as possible to those described in the former part of this paper; such as recesses in the anvil, or in blocks laid thereon, suited to the shape of the steel.

For this purpose the metal is first brought as near as eligible to the size in which it will be used, and then is to be hammered in order to close and condense the metal equally and to the utmost all through, and yet leave every part in a state of rest and ease—a condition extremely essential for good springs, sword blades, musical wire, and every thing that has to vibrate, or act by its tension; for if one part is denser than another, or more at ease, the weaker parts will have most, if not all of the play, and will soon break. And that this is not so often noticed to be the cause as it should be, is shewn by the crudeness of the cure. If a spring breaks, it is frequently replaced by what is called a stronger, that is, a heavier one, losing a portion of the play, and what remains being still upon the weakest parts; so that though it may last longer, yet it ultimately breaks. This may also account for the breaking of axletrees that have appeared sound; for they are subject to such violent shocks as to require every part to yield equably; for the axiom, that the strength of the whole

is only that of the weakest part, rendered less so by the weight and stiffness of the stronger parts, is as truly applicable to springs as to ships.

This second hammering is also to prepare the steel for receiving the utmost hardness, by that peculiar property which it alone possesses — namely, that of receiving a brittle hardness when suddenly cooled from a red heat; but though this hardened steel is brittle, its toughness greatly exceeds that of any other brittle substance.

It is this quality that makes it completely the *master metal,* the one by which we give shape and form to all the others, and fit almost every thing for our use. I must here observe, that this hardness cannot be given in part, it must always be given in full; and so true is this, that in a piece of steel, part of which is hard and part soft, no gradation of hardness can be detected; the soft parts adjacent to the hard ones being quite as soft as any others; indeed, so much so that they have been thought by some to be softer than if slowly cooled. This appearance may be accounted for in the following way: Suppose a rod of well-hammered steel is heated at one end for hardening, there will be a gradation of temperature from the coldest to the hottest end, and the annealing, or reduction of that hardness which it has received from the hammer, will be in proportion to the heat, consequently the rod will be softer and softer towards that end where the heat is applied. On plunging the bar into cold water, that portion which had become hot enough to harden becomes quite hard, and close adjacent to it will be found that part which having been the most annealed, will bear twisting and bending more than any other. But though this hardness must always be given in full, it can be let down in any assignable degree, that is, a

portion of its brittleness may be removed by a moderate heat, and a greater portion by more heat, and so on, as the purposes may require. This is called *tempering;* and if hard steel be brought to a red heat and suffered slowly to cool, it becomes as soft as if never hardened; it is then ready for re-working or re-hardening. This is called *softening*, and is distinguished from *annealing*, which is the same process of slow cooling but applied to steel, iron, or brass, merely to remove all mechanical condensation, whether by hammering, flatting, wire-drawing, bending, or any other work; for if metal has been altered in shape by the hammer or other work as much as it will bear without breaking, then by annealing, it will be softened, and may again be bent or altered as much more; and so on, as often as requisite. Now, as different degrees of heat remove different degrees of condensation received from the hammer, and a white heat removes all, it is of great consequence to harden from the lowest possible heat, in order to retain as much condensation as may be; and it is a fortunate coincidence, that the greater the condensation, the lower is the heat from which steel will harden, and the stronger and tougher will it be. But should this condensed metal be once over-heated, it will no longer harden from that lower degree, but only from a heat near that to which it has been raised; its condensation, with the advantages dependent on that quality, can only be restored by re-hammering. The lowest heat at which steel is generally brought to harden is a dull red, just visible in daylight. Therefore, to be safe, a dull red, only visible in the dark, is chosen for the hammering. At this heat also it can be kept coated with carbonaceous matter, instead of having any burnt out, which is of particular consequence. For this purpose a smith's

forge, in rather a darkish place, having its flat bed even with and near the anvil, is kept smothered with small fuel, the bellows being used only enough to keep the fire alive, so that the gas or smoke cannot burst into flame. The several pieces of steel are laid a little in the half-kindled fuel, enveloped in smoke; this coats them with carbonaceous matter, which the hammering heat can hardly dispel. They are brought in succession from the fire to the hammer, and back again to the fire when too cool; the hammer moves quick, and every part of the steel in close succession is slowly passed under it, and then (the position being changed a few degrees) it is again passed under, and so on, till it has been hammered in every direction, being often reheated; and this is continued as long as the workman thinks it can be of service. Experience teaches him to know by the feel, the sound of the blows, and the lessening degree of impression, when the steel is hammered enough. By such means, and an honest zeal for the goodness of his work, Mr. Walby, whom the Society in the year 1804 rewarded for his hammer, produced the best trowels that probably were ever made; their toughness, spring, and elasticity, seemed carried to the utmost. At this heat the metal spreads much less; but yet, unless confined within a recess so as entirely to prevent spreading, the outer band will be so bad as to require cutting off, it will be so stretched and rent by the pressure of the inner portion.

From what has now been stated, it will be seen that there are two causes for the failure of steel, more particularly if used quite hard. The first is an unequal combination of carbon with the iron, and this is more or less the case with all steel till sufficiently hammered; the toughness of some parts, the brittleness of others,

and the different states of tension hence arising, render the metal very liable to crack, if not in the hardening, yet afterwards, when forcibly struck as medal dies are.

The second cause is bad hammering; for I think I have shewn above, that however much hammered, it yet may be left in a most violently conflicting state, some parts girded and pressed, while others are as powerfully strained, almost to breaking; and if hardened in this state, how can it be expected to stand? and thus springs, though very equally formed, may be very unequal in their strength.

Well-hammered steel requires the least tempering to give it the necessary degree of toughness; but when hardened from a great heat, it loses all the previous condensation from the hammer, and with it so much strength that the toughness disappears, and the same hardness with less strength shews itself in brittleness. Steel, therefore, of this inferior strength, requires more letting down by tempering, to arrive at a degree of toughness enough to bear using. Such tools are too weak and soft for turning steel or iron, and do not stand long for any purpose.

I believe there is a given degree of cold to which the steel must be brought in a given time to cause hardness, also a given degree below which steel will not harden from; and that all farther increase of the heat only weakens the steel, and all farther increase of coldness serves only to harden a greater mass, or a deeper coat of a large mass, by cooling it in the required time.

Steel much over-charged with carbon is too harsh or brittle to receive all the improvement that hammering would otherwise give it; but by choosing the most malleable steel, already sound, and hammering it at a heat so low as to be capable of holding a coat of carbonaceous

matter, it will imbibe the carbon so slowly and in such small quantities during each hammering, as to enable the workman to bring it up to the fullest charge compatible with sound hammering; and so far carbon must improve the strength; but beyond that, brittleness comes on, and it refuses to receive any condensation from the hammer, by which alone toughness is given. It is of no use seeking for hardness unaccompanied by toughness, for we should have to let it down to prevent breaking; yet many believe the hardness to be increased by coming up to this brittleness; therefore, taps, dies, and turning tools, in order to increase their hardness without losing toughness, are allowed to receive a little more carbon on their surface, by putting them in red hot carbonaceous matter for the hardening, the toughness of the metal within remaining the same. For this purpose animal charcoal appears best. I have chiefly used burnt leather, which seems capable of a sort of fusion on the surface of the steel while coming to a red heat, and therefore imparts the carbon much quicker than wood charcoal; and in all cases of hardening it is best to heat the steel in close vessels, or a case of some sort, to protect it from air and prevent carbon burning out of the surface. Water damages the surface at the moment of plunging; to prevent this, small articles are frequently plunged in oil or tallow, which has the reverse effect, for it rather restores the surface. Files and other tools that do not admit of being sharpened are left quite hard, also tools for cutting steel; but in all other cases, to prevent the risk of breaking, the extreme hardness is removed by tempering more or less, as the intended work will allow.

Various methods have been resorted to, in order to measure the exact temper, and more particularly for long

thin articles, such as watch-springs, which are difficult to heat uniformly. Melted metal, the fusing point of which is just under the right temperature, has been used; but if the mercury or other melted metal be in sufficient quantity, and the heat be measured by a thermometer, it will secure accuracy: the article being moved about in this till of the same heat in every part and all through, will be well tempered, let the shape be what it may.

Heating the articles in oil till the smoke rises copiously gives a good temper for tools for brass-work, and a still lower temper is given when the oil catches fire—this is called blazing off; but for articles of any substance, colour is the simplest and most direct criterion. The hardened steel is ground clean along one side and kept perfectly free from greasiness; it is then heated, in preference at the side of a fire to avoid smoke, carefully watching the bright part until it becomes of a straw-colour, it may then be cooled in water to prevent the spread of heat from parts not cared for; this temper suits tools for brass-work; but if heated till it becomes brown bordering on purple, it suits tools for pewter and very hard wood; after this it becomes blue, indicating a suitable temper for the softest carpenter's tools, table-knives, and springs; it is just low enough to bear filing, and in thin pieces will bend a little before it breaks; if heated beyond this it turns grey and is almost visibly red in the dark. Very thin springs are observed to be stiffer while the blue colour is on than when cleaned off; and on reblueing them, they regain their stiffness although there is no alteration of the temper; such springs are therefore preferred with the blue colour on.

These colours may be given to hard or soft steel, and

when cleaned off, the same heat will always restore them. The steel and screws of watches are generally blued for ornament; the other colours, when given merely as a guide in the tempering, are cleaned off. I have found the slow conducting power of lamp black a useful agent to preserve particular portions from being hardened with the rest.

It is sometimes desired to harden the neck of a mandril and not the screw, lest it should break when roughly used: this may be done by an iron tube fitted a little way on the neck of the mandril and ramming the space between full of lamp black, so as completely to envelop the screw, then shut it in by a disk to serve as a wadding; the mandril being then made red hot and plunged in water, the exposed part will be hard, and the covered screw will remain soft.

Steel hardens as well under cover as if exposed, provided it can be cooled in the requisite time; small articles for watch-work have accordingly been hardened quite clean, and their brightness preserved, by filling with them a brass box capable of being shut air-tight while in the fire, and then plunging the box with its contents in the water. On opening the box when cold, the articles are found hard and clean. Very fine drills or wire may be hardened from the flame of a lamp or candle, by merely shaking them quickly in the air, as that will cool them soon enough. Large masses require rapid motion in cold water to enforce their cooling in the requisite time. The largest masses that can be hardened are best done under a waterfall, the force of which beats away the steam as fast as formed, and keeps the surface cool while the central heat is escaping through it; and they should remain in this situation till quite cold throughout; if taken out sooner, the central heat will spread

to the inner side of the hard shell and expand it, while the outside may be cold and therefore will be liable to burst.

I met with an evident case of cracking, when hardening some badly hammered steel which also was unequally carbonized. The pieces were ovals, one inch long, filed out of steel bars one-tenth of an inch thick; they were then hammered, which condensed the middle and stretched the outside; in this state they were heated in a crucible full of charcoal powder (which probably carbonized the outer edge most) and hardened by plunging in water; this cracked them all in the middle, the most condensed part, and none of the cracks extended to the outside.

Stamps and medal dies are an important application of steel; and to enable them to be hardened sound, and to stand in use when hardened, requires the metal to be in a state of perfect ease, the result of equal condensation all through, and this can best be secured by hammering in a recess.

For this purpose it would be very desirable to ascertain by experiments the greatest thickness that can be hardened all through; also the state of carbonization most favourable to the greatest thickness; or, what is the precise difference in this respect between the most mild steel and that which is highly charged with carbon. Likewise, in very large masses, what is the greatest depth from the surface that can be hardened, and whether greatly hammering it would cause any difference in the thickness of the hard crust. This would of course require the pieces so hardened to be afterwards broken to examine the interior; and where a soft nucleus occurred it would require to be ground flat, to shew what sort of boundary

there would be between the hard and soft parts; for it would be rendered visible by the very different texture which grinding produces in hard or soft steel, and there must be some difference in the durability of a block, according as the boundary is well or ill defined.

We are so familiar with small flaws in articles of iron as scarcely to notice them, for their cheapness enables us to use the good and throw away the bad, — such as nails, brads, screws, &c.; but our attention is drawn to large flaws, from the serious consequences likely to attend their giving way.

But in steel nearly the reverse takes place, as it is used so much smaller than iron in things of consequence; therefore the smallest flaws are frequently of as much importance as the largest, for they occasion the breaking of tools, frequently spoiling the work; and when small work is nearly finished, hidden flaws destroy it; they also help to crack large masses when hardening.

But when the utmost efforts of the human mind are transmitted to steel plates, from which the delights of peace and civilization are spread abroad, it becomes of the greatest consequence to avoid every flaw, and even chemical dissimilarity; for though the metal be sound, it may be so unequal in its nature as to etch very badly, and the smallest flaws will spread very broad while drawing into thin plates; and when the etching or graving reaches through to such a flaw, the work is spoiled, laminæ of engraved work frequently coming off, as engravers have already seriously experienced.

For such works, therefore, cast steel should be employed: it should receive an extra degree of forging, to equalize most perfectly its composition and reduce it to a mild state, for on this depends good etching; then

the surface should be watched and kept clear while reducing it to a useable thickness, that no flaws may be beat in: all welding must likewise be avoided, for fear of shutting in flaws; and if rolled into plates, it will require good hammering afterwards to restore the strength or soundness which it loses laterally while rolling. The especial reason why the primary forging should be long and carefully performed, is, that the etching is liable to be rough or smooth, as perfect homogeneity is more or less obtained, and it will be cloudy if different parts of the plate differ in their dose of carbon.

It would be desirable for engravers to make themselves well acquainted with the difference of action of the same acid on pure decarbonized steel, on ordinary steel, and on highly carbonized steel, and also on steel in the softest as well as in the most condensed state; for they would thus judge better whether the defects were in the metal or the acid.

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No. VII.

MACHINE FOR WEIGHING COALS IN SACKS.

The LARGE SILVER MEDAL *was presented to Mr.* JAMES BRABY, *of Duke Street, Stamford Street, for his Machine for weighing Coals in Sacks.*

A BILL having been introduced into the late Parliament, for the sale of coals in the metropolis by weight, instead